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IMPULSE DRYING: HETEROGENEOUS PRESS ROLL SURFACES OFFER NEW PRODUCT OPPORTUNITIES

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ABSTRACT

Research at the Institute of Paper Science and Technology, IPST, has focused on overcoming sheet delamination during impulse drying of heavyweight webs. Laboratory scale experiments demonstrate that high levels of water removal can be maintained while eliminating delamination by using a press roll coated with a low-thermal-mass ceramic. The experiments also suggest that heterogeneous surfaces composed of metal and ceramics can be used to develop unique heterogeneous web structures which may have application in a number of important markets.

KEYWORDS

Impulse Drying   Delamination   Wet Pressing   Heterogeneous Web Structure   Ceramic

INTRODUCTION

Process description.

The impulse drying process under development at IPST employs a heated roll press to activate a more efficient water removal mechanism. During the process, wet paper is brought into contact with a hot press roll, typically heated to between 200°C (400°F) and 400°C (700°F), while pressures between 3 MPa (400 psi) and 5 MPa (700 psi) are maintained in the sheet for 15 to 30 milliseconds. High pressure steam generated at the interface between the sheet and the heated roll surface grows and displaces liquid water from the sheet into a press felt. Since most of the water is removed in the liquid phase, as opposed to conventional drying where all of the water is evaporated, there is a large energy saving.

As the impulse drying process is terminated before the sheet is completely dried, water remaining in the sheet can flash to vapor during nip decompression. Excessive flash evaporation, coupled with low vapor permeability, results in sheet delamination. Research at IPST has shown that by reducing the temperature within the sheet just prior to opening the nip, flash evaporation can be reduced and sheet delamination suppressed. To achieve reduced sheet temperatures, an impermeable low-thermal-mass press roll surface has been designed which provides a high heat flux during nip compression while suppressing heat transfer during later stages of the process.

Review of recent research findings.

Impulse drying simulations have been conducted [1] to compare the performance of a low-thermal-mass (zirconium oxide coated) roll surface to a high-thermal-mass (steel) surface. At a constant dwell time of 20 ms and at three peak pressures, 205 gsm linerboard sheets were preheated to 85°C and then impulse dried from an ingoing solids of 30% over a range of initial platen temperatures from 85°C to 500°C.

Figures 1 and 2 show the water removal, expressed as a moisture ratio change, for the steel and the zirconium oxide coated platens. Water removal increased with increasing initial platen surface temperature. A regression analysis on the data showed that, except at the lowest pressure, water removal was independent of platen type. At a given initial platen surface temperature, the zirconium oxide surface should transfer significantly less energy to the sheet than the steel surface. Hence, water removal must be independent of the total energy transfer to the sheet. Since increasing initial platen surface temperature results in increased water removal, the magnitude of the heat flux at the beginning of the process likely controls water removal.

Sheet delamination limits the operating temperature of impulse drying roll surfaces and consequently limits water removal. Hence, to evaluate potential roll surfaces, the key performance variables were water removal and delamination control. Using z-direction ultrasound to detect and quantify sheet delamination, the platen surface temperature above which sheet delamination occurred was determined.

The zirconium oxide coated platen considerably increased the operating temperature limit at peak pressures of 4.8 and 6.2 MPa resulting in significantly improved water removal.

Platen materials were compared in terms of maximum outgoing solids, maximum sheet density and maximum specific elastic modulus at the operating temperature limits. Figure 3 shows such a comparison, where the results for single felted wet pressing are also included.

Comparing pressing results achieved with both platen types showed similar results. Impulse drying with a steel surface showed no improvement over single felted wet pressing due to sheet delamination. However, impulse drying with the zirconium oxide coated platen at high peak pressures showed significant improvement over single felted wet pressing.

While water removal efficiency is important, enhanced sheet property development is a key advantage of the impulse drying process. As shown in Figures 4 and 5, soft platen sheet density was measured using the ultrasonic test methods. In addition to being a function of initial platen temperature, sheet density also tended to be higher when the prototype platen was used. This result is consistent with the concept that the prototype platen reduced the extent of flash evaporation, which would otherwise result in midlayer bulk.

The out-of-plane specific elastic modulus has been shown to be proportional to standard destructive strength tests such as the STFI compressive strength test [2]. Analysis of the current results showed that the specific elastic modulus was a function of sheet density and platen type as shown in Figure 6. For a given sheet density, the zirconium oxide surface resulted in slightly lower modulus, again suggesting a difference in internal sheet structure. While sheet strength at a given sheet density was lower, the prototype platen allowed operation at much higher temperatures resulting in improved sheet density and strength.

HETEROGENEOUS PLATEN EXPERIMENTS

Experimental objectives.

Comparative experiments with steel and ceramic platens have shown that the thermal mass of the platen surface controls flash evaporation, which in turn controls sheet delamination. Experiments also showed that water removal was independent of platen material at a given platen temperature and that low-thermal-mass ceramic platens can be operated at temperatures significantly higher than those for steel platens without inducing sheet delamination. Comparing the performance of the two platen materials in terms of water removal and delamination control requires that a number of sheet variables remain fixed. Although this was achieved in the previous work, demonstrating the influence of different platen materials on the same sheet would be convincing. Hence, the influence of platen materials on sheet delamination was demonstrated by impulse drying sheets with a platen surface having regions of both high and low thermal mass.

Figure 7 shows the design of a heterogeneous platen used in the experiments. A steel platen was machined such that one-half of the platen was covered by 1/4-inch square steel regions while the other half was covered by 1/8-inch square steel regions. After machining, the platens were plasma sprayed with a zirconium oxide, ground such that there were equal areas of steel and ceramic, and coated with a high temperature polymeric release agent to seal the pores of the ceramic and reduce the free energy of the surface.

Experimental equipment.

Figure 8 shows a schematic of the electrohydraulic press used to simulate impulse drying. 205 gsm linerboard handsheets, formed on a British sheet mold and pressed to 30% solids, were placed onto Nomex press felts containing 16% moisture. The handsheet/press felt combination was then placed onto a wire support where radially injected steam raised its temperature to 85°C. After preheating, the hydraulic system was activated, resulting in a 20ms pressure pulse with a peak pressure of 3.8 MPa and an impulse of 0.034 MPa s. The system was designed so that heated platens made from various materials could be evaluated.

A series of impulse drying experiments were performed in which the initial platen temperature was varied from 84°C to 295°C. Measuring the surface temperature of both ceramic and steel regions it was found that the steel was always slightly higher in temperature than the ceramic. At a low steel surface temperature of 84°C the ceramic was 1°C less. As the initial temperature of the steel was raised to 299°C the ceramic was found to be 9°C less. All reported surface temperatures are averages.

Experimental results.

The surface of the heterogeneous platen was designed to have equal ceramic and steel surface area. The water removal induced by the platen was expected to be the sum of water removed by each area. The water removed by the heterogeneous platen as a function of average initial platen surface temperature is shown on the following figure. Comparison to the previous data shows excellent agreement.

The basic objective of the experiment was to show that regions of the handsheet beneath the steel would delaminate while regions beneath the ceramic would not. As in previous work, z-direction ultrasound was used to quantify delamination. A 3/8-inch diameter transducer was used to record z-directional specific elastic modulus at thirty locations per sheet. Fifteen locations were directly under the 1/4-inch square steel sites, while fifteen locations were directly under ceramic sites. Coefficients of variation of the specific elastic modulus are plotted as a function of initial site surface temperature in Figure 10. Previous research has shown that the onset of sheet delamination corresponds to an abrupt increase in the coefficient of variation of the specific elastic modulus. Hence, delamination under steel sites was observed when the site temperature exceeded 200°C, while delamination under the ceramic site was not observed until the site temperature exceeded 250°C.

Visual observation of the sheets confirmed the ultrasound findings. No visible delamination was noted at average surface temperatures below 165°C. For average surface temperatures between 165°C and 250°C, sheets visibly delaminated only in regions of the sheet in direct contact with the steel sites of the platen. At average surface temperatures in excess of 250°C, large regions of the sheets exposed to both ceramic and steel showed signs of visible delamination.

Figures 11 and 12 show photomicrographs of cross sections through regions of typical sheets in contact with steel and with ceramic at two different platen surface temperatures. The micrographs confirm that delamination occurred in regions of the sheet in contact with steel but not in regions in contact with ceramic.

The photomicrographs and previous data show that sheet properties such as bond strength and bulk can be engineered into sheets at specific localized regions. The ability to develop patterned web structures may have application in a number of paper and nonwoven markets. For example, patterned heterogeneous impulse drying press rolls could be used in the manufacture of patterned towels and in the manufacture of a paper replacement for plastic bubble wrap.

REFERENCES

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2. Orloff, D.I., High-Intensity Drying Processes-Impulse Drying, Report 5 for the Department of Energy Contract FGO2-85CE40738, DOE/CE/40738-T5, September 1990.

ACKNOWLEDGEMENTS

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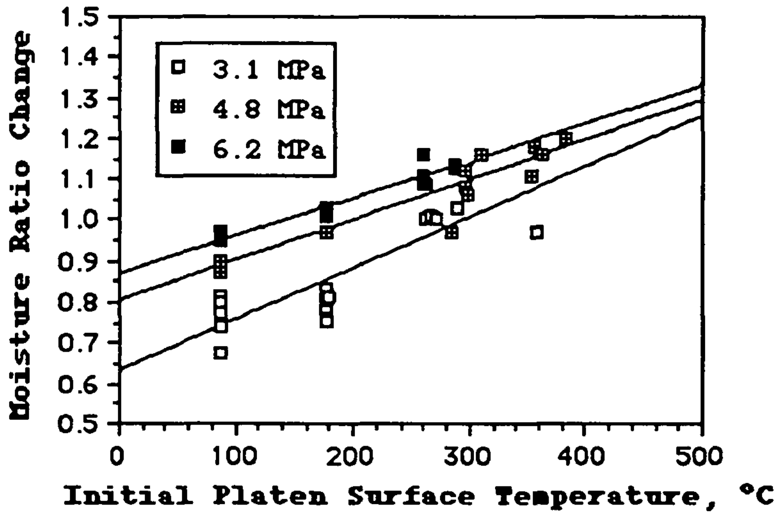

Figure 1. Moisture ratio change for impulse drying with a steel platen as a function of initial platen surface temperature and peak pressure.

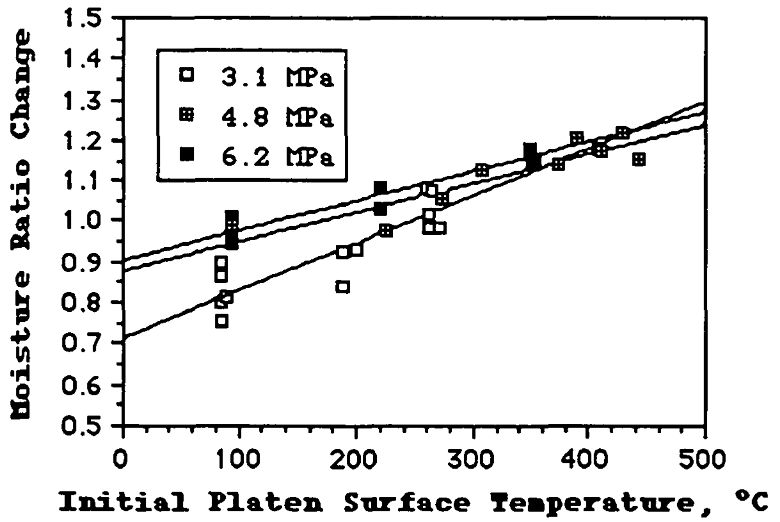

Figure 2. Moisture ratio change for impulse drying with the zirconium oxide coated platen as a function of initial platen surface temperature and peak pressure.

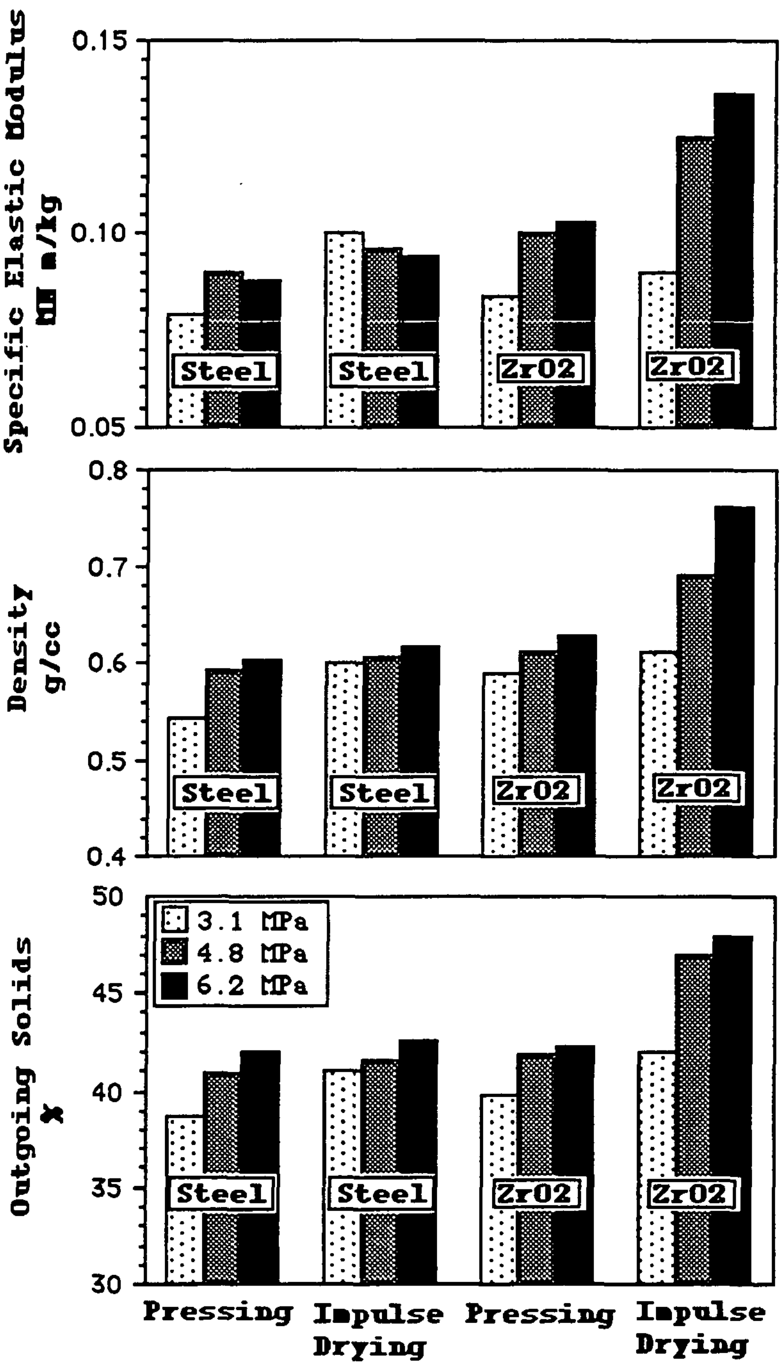

Figure 3: Maximum outgoing solids, soft platen density and specific elastic modulus as a function of peak pressure resulting from wet pressing and impulse drying with a steel platen and with the zirconium oxide coated platen.

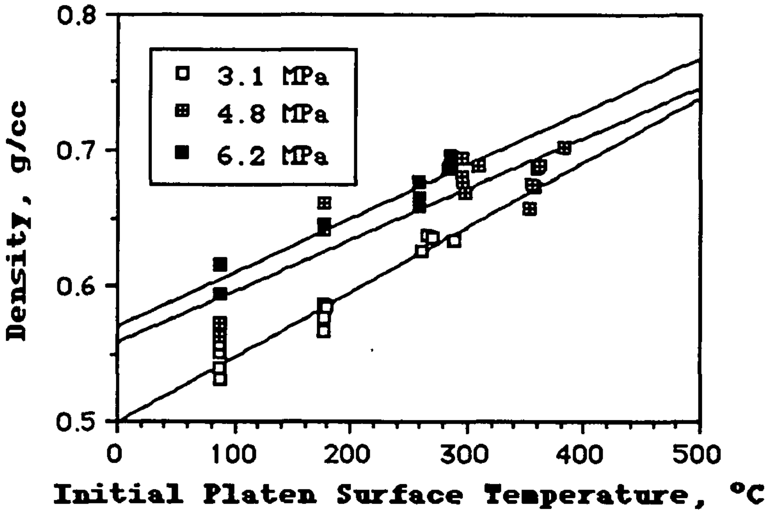

Figure 4: Soft platen density for impulse drying with a steel platen as a function of initial platen surface temperature and peak pressure.

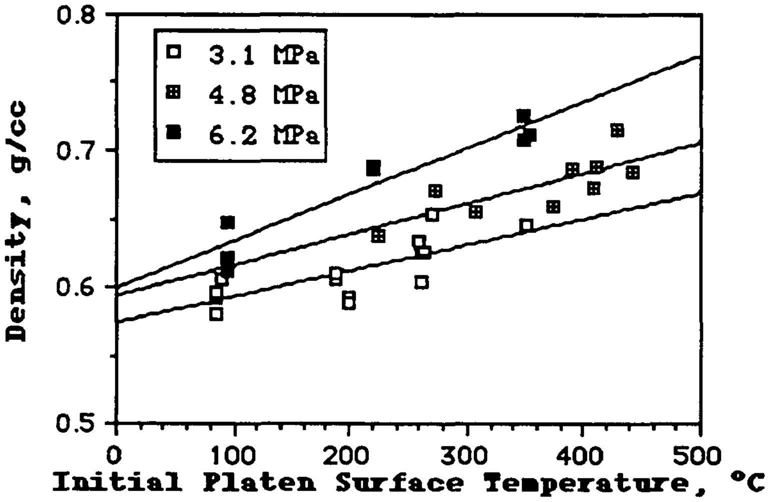

Figure 5: Soft platen density for impulse drying with the prototype zirconium oxide platen as a function of initial platen surface temperature and peak pressure.

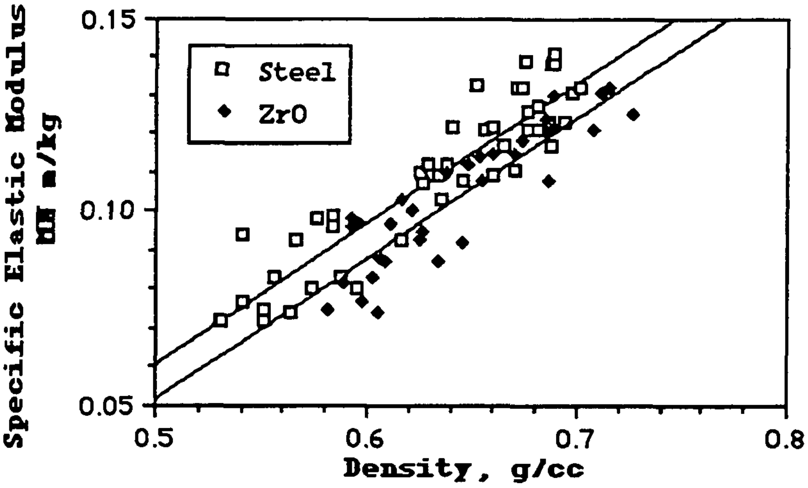

Figure 6: Specific elastic modulus for impulse drying as a function of soft platen density for the steel and prototype zirconium oxide platens.

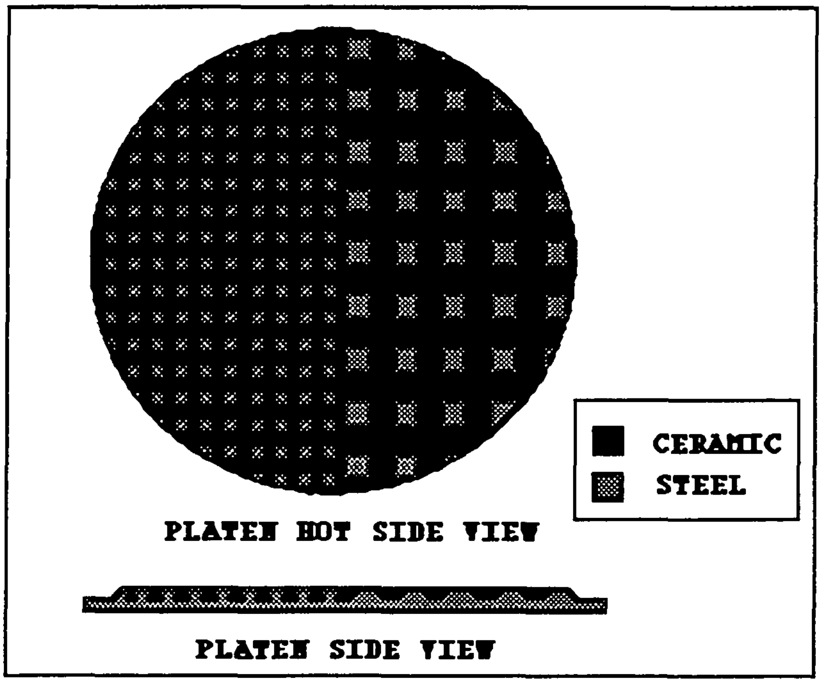

Figure 7. Design of heterogeneous platen.

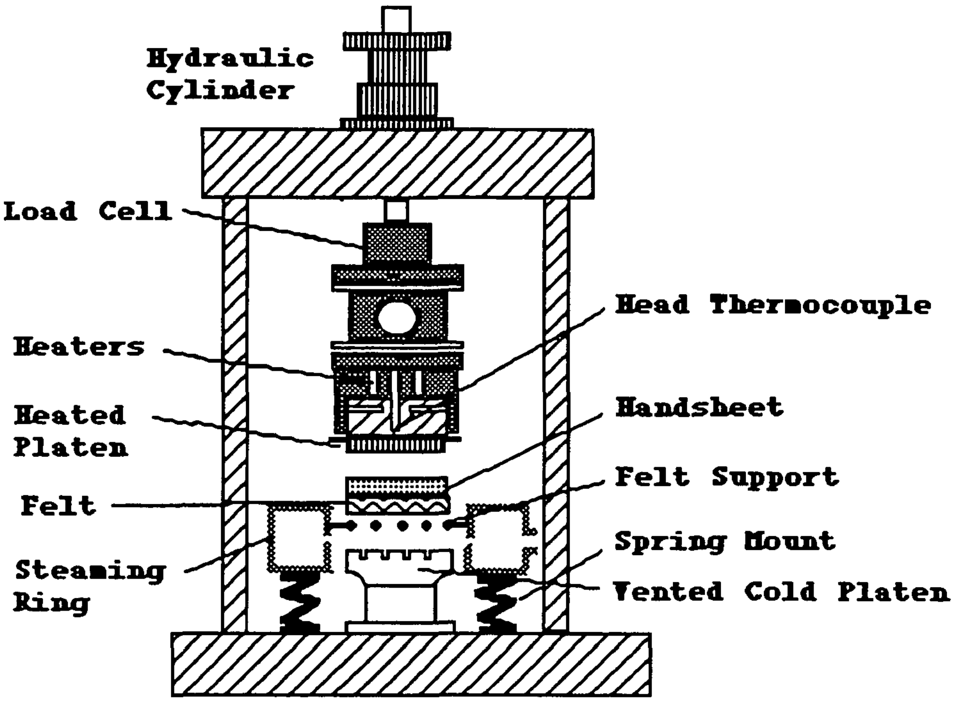

Figure 8. The electrohydraulic press.

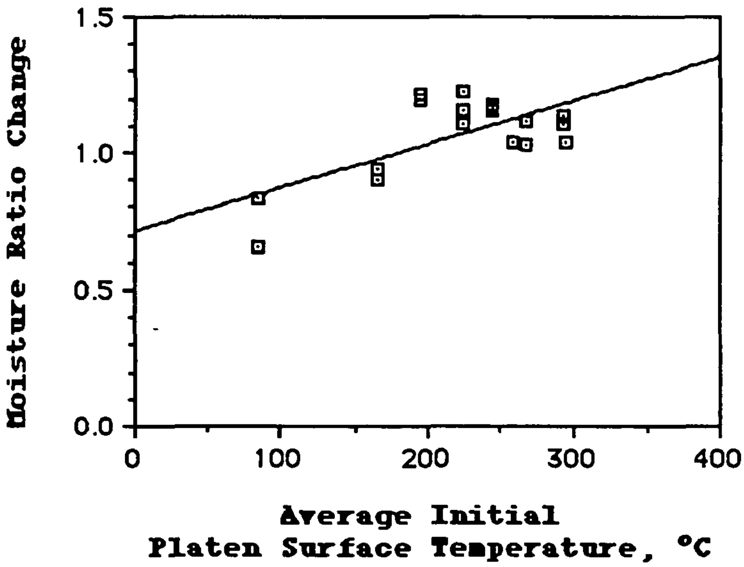

Figure 9. Moisture ratio change for impulse drying with the heterogeneous steel/zirconium oxide platen as a function of average initial platen surface temperature.

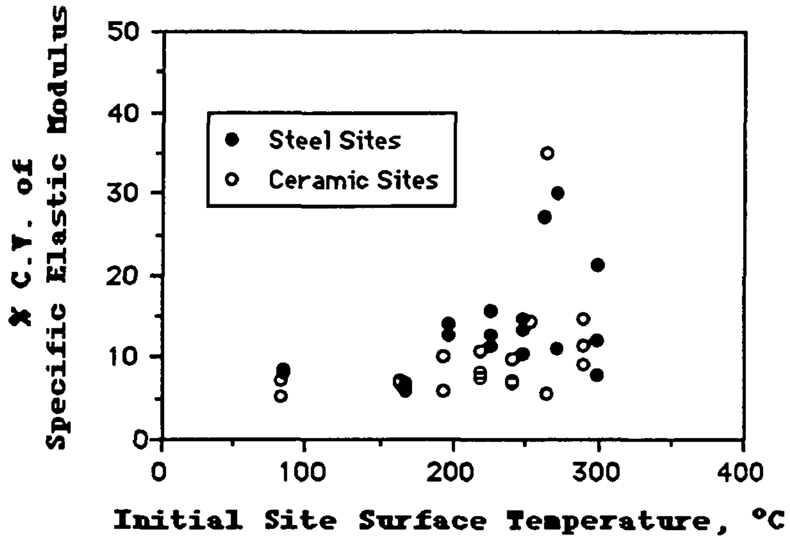

Figure 10. Coefficient of variation of the specific elastic modulus vs. initial site surface temperature.

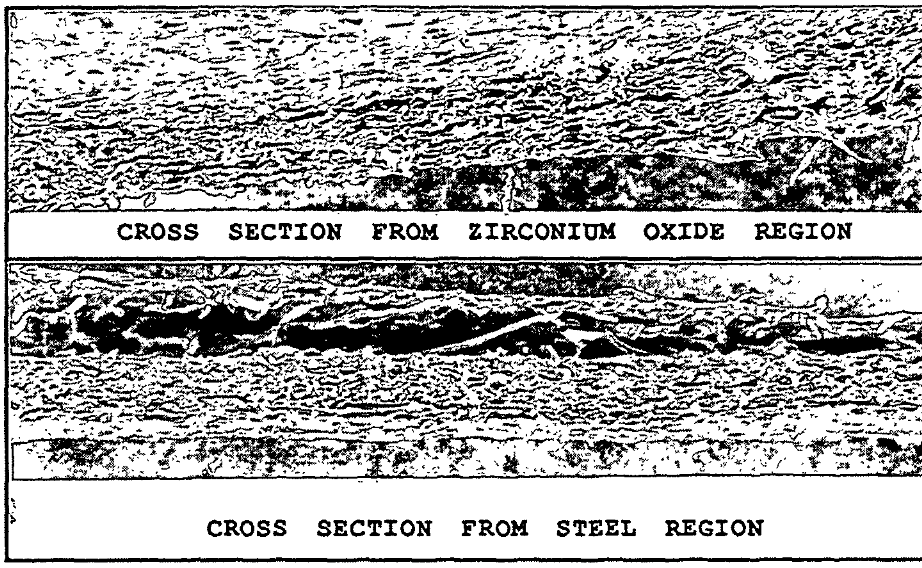

Figure 11. Photomicrographs of two regions of sheet impulse dried at an Initial Platen Surface Temperature of 211°C.

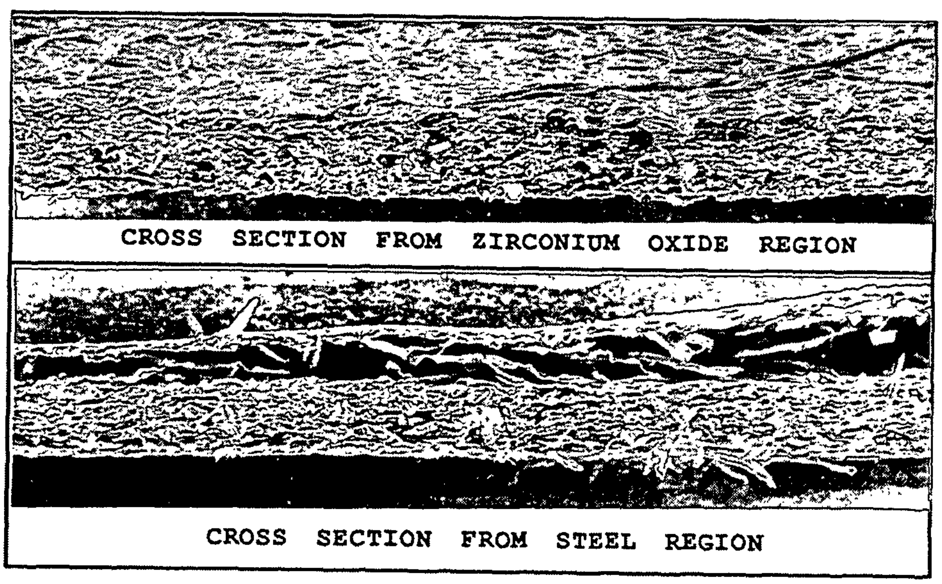

Figure 12. Photomicrographs of two regions of sheet impulse dried at an Initial Platen Surface Temperature of 242°C.